BENEFIT-COST VALUATION

OF LONG TERM FUTURE EFFECTS:

THE CASE OF CO_2

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DISCLAIMER

Introduction and Overview

Benefit-cost analysis has become an accepted tool for evaluation of government investment programs in natural resources during the past few decades.[1] In recent years, it has been tested and applied to a few long term environmental problems including chlorofluoromethanes and ozone, climatic change induced by SST emissions, and to CO_2 induced climate changes.[2]

All of these studies have worked with very uncertain estimates of both costs and benefits. However, each has had a similar set of under-lying problems in assessing results. First, in each case the process of economic discounting of the future has led to small present values for even almost catastrophic future economic losses. For example, a complete loss of the world's GNP in 100 years, growing at 3 percent, would be worth about one million dollars today if discounted at the current prime rate (19 percent as of 3/21/80). If world GNP in 100 years were the same as today's GNP, discounting would reduce the value to only approximately $70,000 presently. Thus, catastrophic losses in the distant future are almost valueless to the present generation if benefit-cost analysis, as it is generally applied, is used in valuing the future. Second, given changing lifestyles, substantial future shifts in technologies, and probabilities of drastic world political-social events, any quantitative measures of benefits/costs in 100 years are not subject to better than 2-4 orders of magnitude accuracy, and may even switch sign, compared wlth

the current economic order.[3] Given these uncertainties, perhaps the best current measure of benefits/costs to future generations is how much current generations would pay to prevent future risks.[4] That is, current decisions on regulation affecting future generations should be predicated on the preferences and values of those now populating the earth's surface. Third, the ethical basis of benefit-cost (B-C) analysis has not been explored to see what forms of bias are introduced when current values are imposed on future generations. It is argued in this paper that the appropriate social rate of discount varies substantially depending on the underlying ethical beliefs of society. Some ethical beliefs lead to discounting future effects to zero (an implied rate of discount of infinity), while others would require valuing future effects at more than present costs or benefits.

It is the purpose of this paper to explore in detail the above three problems of applying traditional benefit-cost analysis to long term environmental choices such as the CO_2 problem and recommend ways that B-C analysis can be altered to accomodate them. The next section explores the CO_2-economic effects problem using a qualitative approach, since actual estimates of benefits for CO_2 control are at this time highly uncertain. The third section contains a development of a set of models demonstrating how future economic effects may be valued differently depending on underlying ethical beliefs. The fourth section provides an example of one approach to assess the present generations preferences on environmental risk to future generations. The final section contains a listing of research recommendations on how the CO_2 problem can be studied from an economic perspective, given the findings of previous sections.

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CO_2 Effects -- A Qualitative Economic Assessment

The CO_2 problem from the standpoint of an economic perspective has its most interesting elements in terms of intergenerational choice. The reason for this is the anticipated positive economic benefits accruing for several generations and the potential disasterous economic costs that may accrue to generations after that. In the NAS Geophysics Study Committees report, Energy and Climate, several potential physical and environmental effects of increasing CO_2 are rather dramatically proposed over a period of 170 years.[5] They include the "melting of glaciers" causing rises in the sea level of 3-5 meters, a potential shift in agricultural zones upward in latitude in the northern hemisphere with an expansion of frostfree days, rates of photosynthesis, and production of biomass in most regions of the world along with expansion of arid and semi-arid regions. Thus, from a qualitative perspective there may well be substantial benefits to agriculture, forestry, and other natural resources that are highly temperature dependent in terms of productivity.

In Figure 1 is a world map adapted from W.W. Kellogg (1979) indicating potential temperature changes by latitudinal zone given a doubling of atmospheric CO_2.[6] A rather arbitrary line divides the world into drier and wetter zones based on the altithermal period occuring 4-8 thousand years ago. If this line between drier and wetter is accurate, it presents a whole series of economic difficulties in assessing benefits and costs. For example, there is a lot of uncertainty as to where the line should pass through the continental United States and if, for example,

the Northern Great Plains and Midwest were significantly drier and warmer, this would suggest a wholly different set of adaptive policies and thereby benefits or costs as contrasted to a warmer/wetter area. The same difficulty arises for the Soviet Union in terms of wheat yields. The line bisects the Soviet Union where only slight error in drawing it would make the winter wheat crop more or less vulnerable. If there was more variation in the hydrologic cycle in the wetter zones identified in Figure 1, this could induce greater variations in crop yields and thereby cause substantial impacts to agrarian communities on the food threshold. This is particularly true for the Asian cultures dependent on the monsoon season. It would also be dependent on the possibilities of new varieties of crops which are either more drought resistant or water tolerant in their root zones (Wittwer, 1979).[7]

A drier climate in the Northern Great Plains of the U.S. would cause an increase in the probability of crop failure in any one year. This would also be true for the Midwest in terms of dry land farming. Over a very long time, the Midwest, through development of substantial irrigation systems, could possibly even increase yields above those existing currently but at a substantial capital cost (i.e., $30-50 per acre). In addition to the direct agricultural effects and impact on growing seasons, a substantially warmer climate would undoubtly mean a reduction in heating costs,[8] a potential increase in air conditioning costs,[9] a movement towards or away from an optimal urban environment depending on the initial location,[10] a potential increase in diseases (particularly in the tropical zones) such as elephantiasis and dingue fever, and

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TEMPERATURE
CHANGE

180   90W   0   90E   180   90N 9°c-11°c

DRIER   DRIER

WETTER   DRIER   ?   DRIER late in period — ? ?

WETTER ?

40N   DRIER ?   ? ?   40N 4°c-5°c

WETTER WETTER WETTER ? WETTER

WETTER WETTER WETTER WETTER

0 2°c-3°c

WETTER ?
late in period

WETTER
late in
period   WETTER   40S 4°c-5°c

90S 9°c-11°c

180   90W   0   90E   180

Figure 1. Potential Climatic Change and the Altithermal Period (4000-8000 years ago).

Source: Adapted from W.W. Kellogg, "Influences of Mankind on Climate," Annual Review of Earth and Planetary Sciences, (1979). Temperature changes were formulated in discussions at the Aspen Institute Workshop on "The Consequences of a Hypothetical World Climate Change Produced by Atmospheric Carbon Dioxide," Wye Plantation, Maryland, February 25-29, 1980.

greater capital requirements for reducing the growth of molds of relatively high humidity locations. In addition to changes in location of agriculture, there would be an implied movement of population and thereby the location of urban areas. Whether such a movement would be rapid and substantial enough to induce large adjustment costs is not now know. [11] The cost of adjustment would depend substantially on the depreciation rate for existing capital assets and if the adjustment time is slow enough, such costs might be minimal. [12]

A significant issue in terms of qualitative economic assessment is that almost all of the studies completed to date on quantitative economic impacts have examined only the equilibrium costs of a very small long term temperature change in the range of less than one degree centigrade globally and there is a great deal of uncertainty as to how measurements for such small changes can be extrapolated to changes ranging from 4-5° centigrade in the temperature zones. In Figure 2 are recorded a long run equilibrium costs of a temperature change. By equilibrium we mean the additional costs of producing in a new state with a higher or lower temperature as contrasted to the current state. Equilibrium costs do not take into account the path of adjustment towards the new equilibrium or costs that may be incurred depending on how rapidly adjustment occurs. Given the very long term nature of the incremental temperature change induced by CO_2 forecasted so far, it appears that looking only at equilibrium costs may be an appropriate strategy. in Figure 2, the original CIAP results are presented along with an estimate by Laurman (1979) fitting a curve to the CIAP results and finally two paths where the CIAP results have been updated in terms of current information. [13] The updated
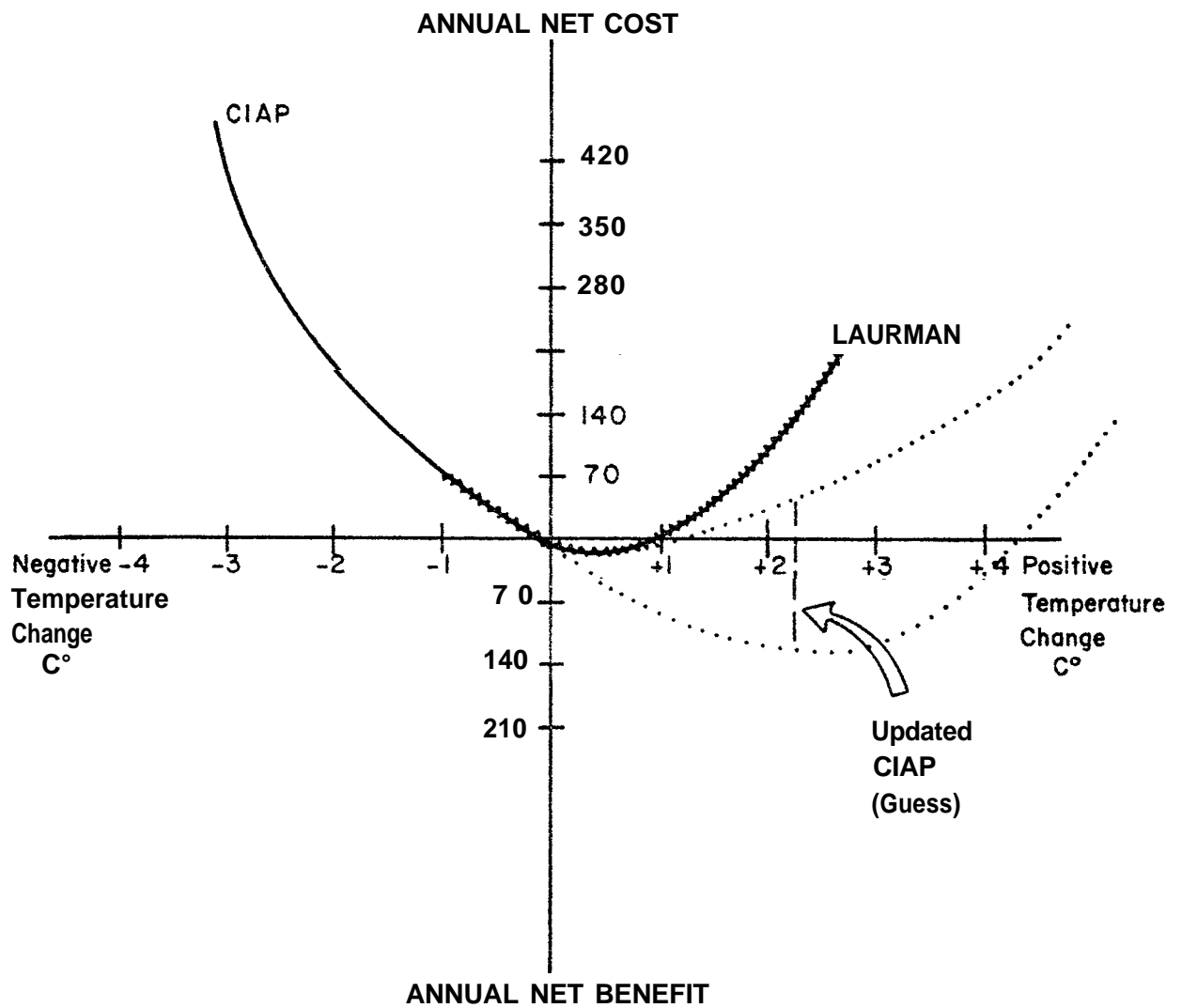
Figure 2. Equilibrium Costs and Long Term Temperature Change.

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CIAP paths are highly sensitive to assumptions on energy used for heating and cooling and therefore may be highly inaccurate. Note that these costs or benefit estimates on an annual basis are not all inclusive as they do not include costs of increased potential costs of diseases, more arid regions, or the net benefits of utilizing current fossil fuel energy. If the net benefits of using fossil fuel energy currently were added on to this diagram, it would indoubtedly pull the updated CIAP curves down substantially. While Laurman assumed a type of symmetry of the CIAP results in terms of positive and negative temperature changes, this is un-likely to be true because of the difference in sectors being impacted as well as the sensitivity of sectors in response to warming versus cooling and to more or less precipitation. Perhaps it would be worthwhile to stress at this time that the CIAP results were inclusive of only about twenty percent of the world economy and were primarily derived for nega-tive temperature changes as opposed to positive ones. The uncertainties on the positive side are clearly due to the fact that there has yet to be a comprehensive study of CIAP dimensions for rising temperatures.

In summary, the existing set of cost and benefit estimates for a positive temperature change of the magnitude suggested by CO_2 modeling efforts have as yet to be adequately assessed. However, in qualitative terms without substantial changes in precipitation patterns, a warming should: (1) increase crop yields; (2) extend growing seasons; (3) allow a greater variety of crops over larger regions; (4) reduce heating costs; (5) provide a more desirable urban climate in the temperature zones; (6) (may) induce higher tropical disease rates; (7) increase air con-ditioning costs and change styles of living in the tropical tones;

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(3) require the development of capital intensive irrigation systems or crop adaptation in some areas; (9) reduce urban costs of snow removal and thus in general transportations costs; (10) require substantial capital investments to accomodate a rising level of ocean; (11) reduce costs (or increase benefits) of producing fossil fuel energy. Whether all of these taken altogether add up to a net positive cost to society is unclear at this time. It appears reasonable to presume, however, that given the existing quantitative evidence for these sectors, that very small positive changes in global temperature in the range of 0-2° centigrade, would be beneficial to at least the next several generations. Given the highly incomplete and tentative findings on equilibrium costs and benefits, the CO_2 problem might be visualized as is depicted in Figure 3. That is, for a period of perhaps up to 100 years, there is likely to be a net annual benefit from increasing levels of CO_2 in the atmosphere. Beyond that time, however, as the climate becomes distinctly warmer with greater variability in precipitation patterns and a finite probability of melting the antarctic ice caps, the potential for very large future economic costs increases. Thus, we visualize the CO_2 problem, in simple terms, as a problem of tradeoffs between succeeding human generations where the first few benefit substantially by imposing perhaps very large costs on future generations. This is suggestive that the CO_2 problem is really one of intergenerational choice. That is, comparing a distinct positive benefit stream to one set of generations with the highly uncertain but very large potential economic cost to generations that follow. If this paradigm is accepted, then the question arises as to whether benefit-cost analysis, in its traditional form based on discounting of the future and not

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More Arid Regions(?)
Possible melting of
West Antarctic Ice
Cap. Rise in ocean
levels new investment

NET COSTS (Annual)

NET BENEFITS

O

25   50   75   100   125   TIME
(years into
the future)

Increased Rates of Photosynthesis
Agricultural Production (Area and Timing)
Reduced Heating Costs
More Desireable Urban Climate
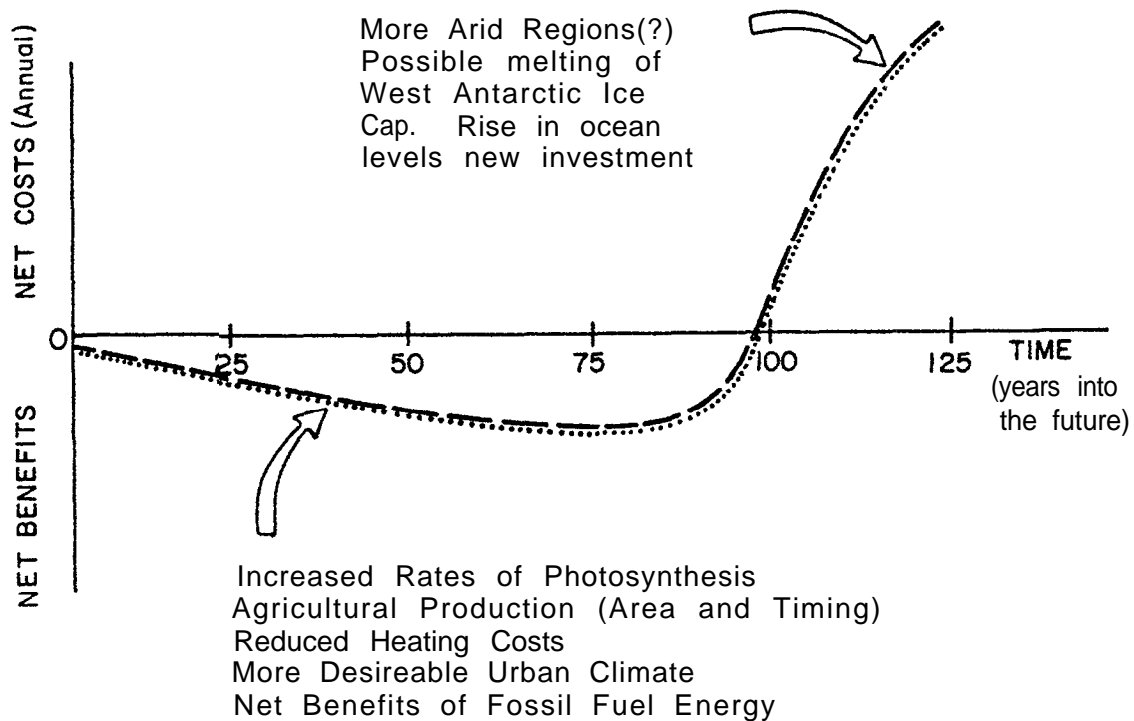Net Benefits of Fossil Fuel Energy

Figure 3. Long Term Net Costs of Climatic Change: A Qualitative Picture

requiring compensation of losers by the gainers, is an appropriate tool for evaluation.[14] We believe in its present form it is not, in that even with extremely large future costs, small current benefits will dominate the decision on control. Thus, traditional benefit-cost analysis must be disregarded as a valuable tool for policy making in making current decisions on the CO_2 problem. In what follows we attempt to devise a new methodology whereby the future can be accurately and efficiently pro-tected given current choices.

Ethics and Climate Change

As expressed in our introduction, one way of formulating the CO_2 climate problem is as an ethical question. This section attempts to ex-plore the notion of both the nature of ethical systems and how such systems might help clarify the CO_2 climate problem. In addition we briefly indi-cate how alternative ethical systems might be integrated with benefit-cost analysis. We find that the critical parameter is the choice of discount rate.

Economists justify use of a discount rate on future benefits and costs-- weighing future economic values less than current economic values--as follows: imagine that one individual 100 years from now is forced to evacuate a coastal area as a result of CO_2 emissions from burning coal today. Further, let us assume that the future individual would accept a payment of $100,000 as "fair" compensation for property losses and any risks imposed. If we, the current generation wish to compensate that future individual do we need to set aside $100,000? Is the damage now the same as the damage 100 years hence? The usual economic answer is "no."

If we were to invest $4,979 today in a bank account paying a 3% real rate of return (over inflation) we would have $100,000 of real value in accumulated interest and principal 100 years hence to compensate the displaced future individual. Thus, the argument goes, a 3% discount rate would be appropriate on damage done to future generations in making decisions today. For example, If scrubbing CO_2 from stack emissions or finding a $non-CO_2$ emitting energy substitute for coal--solar or nuclear for example--were to have an excess cost of more than $4,979 today, benefit-cost analysis would suggest not to bother, even though we will do $100,000 worth of harm 100 years hence.[15]

Many would, of course, view such a decision as unethical. Page (1977), for example, argues that compensation is likely to be only hypothetical and not real, making the whole discounting procedure meaningless on ethical grounds since actual compensation is not likely to be paid.[16]

The ethical-economic issue outlined above--that of discounting--critically affects an analysis of the $CO_2-climate$ problem For example, J.A. Laurman concludes, based on a benefit-cost study done for the Electric Power Research Institute, that "since no agreement on the correct treatment of social discounting exists, we are unable to present conclusive estimates of present day discounted costs for the $CO_2-climate$ change problem.[17] Thus, in what follows, we develop and define the notion of an ethical system where we focus on distribution since the discount rate is the critical parameter in questions of intergenerational distribution. We find that differing ethical systems imply differing discount rates.

Ethical systems attempt to provide a mechanism for answering the question: "Is a contemplated action right or wrong?"[18] An ethical system

can take the form of a list of rules. Examples of this first class of ethical systems include such specific lists as the Ten Commandments and Kant's Categorical Imperative, which states: "Act only on the maxim whereby thou canst at the same time will that it should become a universal law." Note that the Ten Commandments provide a list of specific behavioral rules while Kant provides a mechanism for generating such a list. The difficulties with lists, however, are first that some of the rules may well come into conflict (be inconsistent) under some circumstances, as a result requiring a hierarchical ordering of rules to resolve conflicts. Second, such lists, if explicit, may fail to cover certain eventualities.

An alternative specification of an ethical system can take the form of a criterion for evaluation. Thus, for example, "do unto others as you would have them do unto you," can be applied to nearly all ethical behavior decisions. Similarly, the statements "turn the other cheek" and "individuals should have freedom of choice where no one else is bothered" imply that ethical behavior involves not harming others inclusive of future generations under any circumstances, and yield a general criterion or decision rule.

The latter approach, ethical systems based on ethical criteria, can generally be incorporated into economic analysis by reweighting benefits and costs according to the particular criterion. The former (i.e., lists) is potentially much more difficult to treat, in that a list of rules would become a set of mathematically specified constraints to a decision process such as benefit-cost analysis. Thus, in this exploration of ethics and economics we will focus on ethical systems which take the form of general criteria.

A second difficulty in merging ethics and economics is the possibility that an ethical criterion and a basic assumption of economic analysis are incompatible. An example is the democratic ethic--what is "right" is what the majority approves. Arrow has shown in his impossibility theorem that majority voting may imply intransitive social preferences. Transitivity is a fundamental assumption of economic theory necessary even for the basic concept of economic efficiency. Economic analysis thus requires that "if situation A is socially preferred to situation B and B to C, then A is preferred to C." However, even if individuals are transitive in their preferences, Arrow has shown that majority votes can result in social preferences of the "situation A is preferred to B, B is preferred to C, but C is preferred to A" (intransitive) type. Thus, we also require that the ethical criteria employed be transitive.

These requirements, which imply that an ethical system can be represented as a transitive criterion for individual or social behavior, leaves at least four ethical systems (and probably more) for analysis. Three of these, Utilitarian, Rawlsian and Nietzshean have been identified by Alexander.[19] We describe these as well as a Libertarian ethic in detail below where for each ethic we briefly examine implications for an example "moral" question as well as for distribution of income.

Utilitarian (Benthamite). A Utilitarian ethical system requires "the greatest good for the greatest number" as expressed by Jeremy Bentham (1789), John Mill (1863), and others. The socal objective is to maximize the sum of the cardinal (measurable) utilities of all individuals in a society. Thus, for an individual to take an ethically "correct" action all consequences of that action must be considered. The Utilitarian ethic has a pragmatic

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consequentialist character, which, in a matter of fact way, is quite appealing. For example, in analyzing the question "should a dying person be told of a terminal illness by a friend?," a Utilitarian would compare the gain in the dying person's utility from not knowing of impending death to all the possible losses resulting from lying about the person's health. These losses are complex in that: (1) the dying person may later discover the lie and feel worse yet about being lied to; (2) if the lie is discovered, the liar may not believe in the future, causing a possible utility loss to the liar; and, (3) since social organization depends on honest communication and believability of information, a small utility loss is possible to each of many people in the sense that every lie told reduces the believability of all statements.[20] If the utility gain exceeds the utility loss across society of telling a lie, the lie is "right." If the utility gain is less than the utility loss across society the lie is "wrong."

In addition to the obvious difficulty in making all of the requisite calculations necessary for moral choices, a fundamental problem afflicts utilitarians--measuring utility. The problem of distributing income will serve to demonstrate the problem of measureable or cardinal utility. First, if we make the assumption, consistent, for example, with the views of Pigou (1920) that all individuals have the same utility function then total utility for a society will be maximized by giving everyone the same income. (For two individuals or generations, A and B, with identical concave utility functions, $U_A(Y_A)$ and $U_B(Y_B)$, with incomes Y_A and Y_B respectively, the maximum of U_A+U_B will occur where $Y_A=Y_B$ with constrained total income equaling (Y_A+Y_B).

If, on the other hand, we assume different individuals have different utility functions, e.g., Edgeworth in Mathematical Psychics argues that the rich have more sensitivity and can better enjoy money income than the poor, we end up with a situation where total social utility is maximized by providing unequal incomes. Thus, in Edgeworth's view, a rich individual (Mr. A) by his sensitivity should have more money to be used in appreciating fine wine than a poor individual (Mr. B) who is satisfied with common ale (where $U_A(Y) > U_B(Y) \quad \forall Y$).

Obviously then, depending on beliefs about measurable utility functions, any distribution of income across individuals or generations can be justi- fied, ranging from a relatively egalitarian viewpoint (Pigou) to a relatively elitist viewpoint (Edgeworth).

There do exist ethical systems which are totally egalitarian and totally elitist. These diametrically opposed systems, as explored by John Rawls and Friedrich Nietzsche, respectively, are described next.

Totally Egalitarian (Rawlsian). Rawls proposes that the well being of a society is measured by the well being of the worst off person in that society. [21] This simple notion would lead, if adopted, to a totally egali- tarian distribution of income. However, before examining the distributional consequences of a Rawlsian ethic, let us again examine the case of lying to save the feelings of a dying person.

The problem from a Rawlsian view centers on just who is the dying person. If he or she is a worse off, or the worst off individual in society, only the effect on the dying person need be considered. The effect of the lie on everyone better off (higher level of utility if we accept cardinal utility consistent with Rawls' analysis) is of no

consequence whatever . Thus, assuming the dying person is worse or worst off, the lie is ethically correct if the dying person is made better off, which is likely to be the case if the lie will probably go undiscovered.

But, if the dying person is better off, i.e., very rich, should his or her feelings be saved? Rawls would likely say no. Any negative consequences of telling the lie to the liar, e.g., his truthfulness might come into doubt, would make a worse off individual, worse off inconsistent with an egalitarian ethical position. However, from a Rawlsian view, the dying friend is likely to be considered worse off, and if a lie makes him better off, then the lie is "right" without reference to the burdens the lie might place on family and friends.

The Rawlsian criterion can be expressed mathematically as follows: For two individuals A and B, where utility is denoted U, if $U_A < U_B$, we maximize U_A subject to $U_A \leq U_B$. If $U_B < U_A$ then we maximize U_B subject to $U_B \leq U_A$. Note that, if we can reach a state where $U_A = U_B$, then we maximize U_A subject to $U_A = U_B$. The implication of this for redistribution of income is that we would try to add income to the worst off individual, possibly taking income away from wealthier individuals, until he catches up with the next worst off individual. In this ideal state where a "perfect" distribution of income can be achieved, we would then add income to both Individuals until their utility levels (well being) have caught up to the third worst off, etc. Eventually this process would lead to a state where $U_A = U_B = U_C = U_D$ . . . for all individuals in a society, where all utilities are identical. This criterion can be written more compactly for a two person society as max min $\{U_A, U_B\}$, so we are always

trying to maximize the utility of the individual with the minimum utility. Implicit also in Rawls' arguments (e.g., the veil of ignorance) is the assumption that individuals' utility functions with respect to income are about the same. Thus, a Rawlsian ethic would work towards a relatively equal distribution of income based on need both across individuals and generations.

Totally Elitist (Nietzschean). A Nietzschean criterion can be derived as the precise opposite of the Rawlsian criterion discussed above. The well being of society is measured by the well being of the best off individual. Every act is "right" if it improves the welfare of the best off and "wrong" if it decreases the welfare of the best off.

Lest the reader dismiss the Nietzschean criterion as irrelevant for a Western democratic society, a number of elitist arguments should be mentioned. The gasoline shortage of the Summer of 1979 moved Senator Hiyakawa of California to comment, "The important thing is that a lot of poor don't need gas because they're not working." Economic productivity can, in this sense, rationalize a defined "elite."[22] Thus, concepts of merit can be elitist in nature, e.g., those who produce the most "should" have the largest merit increases in salary (even though they may already have the highest salaries).

The case of lying, for the benefit of the best off is, from an elitist position, clearly acceptable. To hurt the feelings of someone better off is immoral. For the elite to insult the poor is "right." Thus, some arguments for respect for authority of status can be elitist. Further, if the best off (supermen) can be made better off by lying to the worse off, that is "right" as well. Should one lie to a dying man about his

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death? If the dying man is considered to be worse off already, the living should not reduce their well being (any disutilities from lying) for a "lost cause." However, if the dying man is viewed as a "superman" his interest should prevail.

Income distributional questions are a bit more complex in that the solution is not simply to give all of society's wealth to the best off. This occurs because, if between two individuals A and B we are attempting to

$$\max \max \{U_A, U_B\}, \tag{1}$$

or to maximize the utility of the individual who can attain the greatest utility we must first find the solution for max U_A and then separately for max U_B and then pick whichever solution gives the greatest individual utility. Obviously, it will usually be better to keep B alive to serve A, i.e., contribute to his well being, than to give B nothing if A is to be best off. Thus, subsistence is typically required for B. Similarly, if we have two succeeding generations, it may well be "best" for the first generation to save or not contribute to CO_2 build-up as much as possible to make the succeeding generation better off. Thus, an elitist viewpoint may support altruistic behavior between generations.

Libertarian. The last of our ethical systems is an amalgam of a number of ethical principals, embodied in part in a Christian ethic, "turn the other cheek," as well as in the U.S. constitutional viewpoint that individual freedom prevail except where others may be harmed. These views have been formalized by Nozick in a strict Libertarian framework.[23] We are not concerned here with changing the initial position of individuals in society to some ideal state, but rather in benefitting all, or at least preventing harm to others, even if they are better off. This ethic has

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been embodied often by economists in the form of requiring "Pareto Superiority," that all persons be made better off or at least as well off as before.   Any act is then immoral or wrong if anyone else is harmed. Any act which improves an individual's or several individual's well being and harms no one is moral or "right."   The acceptance of the initial social position, even if elitist or highly unequal in income distrubtion as part of a Libertarian ethic does not, however imply consistency with an elitist ethic.   Nietzsche, for example, rejects this view as a "slave mentality" in attacking Christianity.

As an example application, again consider the ethics of lying to a dying person.   If the person benefits, the criterion is partially satisfied (no harm has come to him or her). However, it is argued that any lie must cause some social harm (see Bok, 1978) or at least negatively affect the believability of the liar.   Thus, under a Libertarian ethic, the liar must be harmed, so telling the lie is "wrong." Thus, even in the case of a dying person, to lie about his or her condition would likely impose harm on those maintaining the lie, making the lie "wrong." These arguments are essentially consistent with the views of St. Augustine who maintained that all lies are wrong, i.e., all lies are sins requiring pardon. The Libertarian ethic would then tend to prohibit all lies, even where some net benefit could be shown in a Utilitarian context.   This occurs because one can argue that any lie does harm to someone.   Finally, the Libertarian ethic is especially applicable in that rarely does anyone wish to be lied to, even if the lie is supposedly in the interest of the one deceived.

The Libertarian ethic does not define a best distribution of income. Rather, the criterion requires that any change from the existing social

order harm no one.   If, for example, Mr. A and Mr. B initially have incomes Y_A^0 and Y_B^0, we then require for any new distribution of wealth (Y_A, Y_B)--for example more wealth becomes available--that

$$U_A(Y_A) \geq U(Y_A^0) \tag{2}$$

and

$$U_B(Y_B) \geq U(Y_B^0) \tag{3}$$

or each individual must be at least as well off as he initially was. Any redistribution, e.g., from wealthy to poor or vice versa, is specifically proscribed by this criterion. Thus, this criterion while seemingly weak, i.e., it does not call for redistribution, can block many possible actions if they do as a side effect redistribute income to make anyone worse off, however slight the effect may be. Often then, to satisfy a Libertarian criterion requires that gainers from a particular social decision must actually conpensate losers (for a discussion of compensation, see E.J. Mishan, Introduction to Cost-Benefit Analysis, 1971).

The four ethical systems presented above are, as noted, by no means exhaustive. While some, such as a democratic ethic, have been excluded on technical grounds, others must await future treatment in our analysis. However, a Darwinian or Objectivist ethic--survival of the fittest--may imply that the existing distribution of income is ideal--derived from competition between individuals in society [24] (A. Rand,, The Virtue of Selfishness, 1964). Thus, a Darwinian ethic may justify traditional benefit-cost analysis, unweighted net addition of benefits and costs or even allowing future generations to completely "fend" for themselves! Of course, the rules under which that competition occurs may come under question. For example, is lying permissible in a business contract? In any case, the

four ethics chosen here do have the advantage of simplicity, but may in turn represent at least in their mathematically specified forms--necessary to utilize them in benefit-cost analysis--considerable oversimplifications.   All ethical systems as logical constructs may, however, suffer from this charge.

William Gass argues that individual ethics are part of common sense. [25] He uses the example of an ethical "experiment" in which an "obliging stranger" is lured to the home of the experimenter.   The experimenter knocks the stranger out and puts him in an oven at 450°, but overcooks his new guest.   Gass, after telling the story, then asks why everyone would agree the experiment described is unethical.

A Utilitarian might argue that the experiment is wrong because any social utility from the experiment would be less than the disutility to the obliging stranger.   An egalitarian would argue that to be dead is highly unequal, a Kantian that the categorical imperative was violated (e.g., it would not be a good universal law for all mankind to cook obliging strangers), and the Libertarian rejects the experiment since the experimenter would not likely want himself cooked by an obliging stranger.   The point is that one hardly needs an ethical system to tell right from wrong, rather moral knowledge exists in and of itself.   However, for benefit-cost analysis the difficulty of measuring ethical values directly would require nonmarket information of an unusual kind.   For example, one could ask an Individual how much he would be willing to pay for redistributing income to the less fortunate.   Ethical beliefs would be captured, and policy issues could be evaluated on a distributional basis with such information.   This approach is taken in the next section   Here we will explore the implications of

weighting benefits and costs across generations with the four ethical systems descirbed above. We are thus imposing a set of external ethics on a particular benefit-cost problem at this point rather than trying to incorporate ethical values of individuals into the calculation of benefits and costs which we discuss in the next section.

Here we explore the issue of discounting using a two period model of climate change resulting from combustion of fossil fuels.[26] The strategy is to model the welfare or utility of the present generation, U_1, to compare to the expected utility of future generations, $E(U_2)$. We try to capture two explicit features of the decision problem. First, current depletions of fossil fuels by the present generation, D_1, reduce the availability of fossil fuels for future consumption. Thus, if the initial stock of fossil fuels is S, the remaining quantity available for future generations, is $D_2 = S - D_1$. Second, depletion by the first generation results in the possibility of losing a fraction $f(D_1)$, $0 \leq f \leq 1$, of the capital stock, K_2, of future generations. This might occur because of flooding of coastal areas and because of more variable future climates, making immobile capital stocks useless. We assume that climate change is uncertain so there is a probability P_f, of the reduction of the future's capital stock from K_2 to $(1-f) \cdot K_2$.

Utility of the initial generation then depends on available consumption. Initial output, F_1, is taken to be a function of the capital stock K_1 (given for our analysis) and fossil fuel depletion D_1. Thus, output in period 1 is

$$F_1 = F(K_1, D_1) \qquad (4)$$

where F is a strictly concave production function. Where the first genera-
tion's investment in future generations is given as I_1, consumption of the
first generation is $F_1 - I_1$ so utility of the first generation is

$$U_1(F_1 - I_1). \tag{5}$$

Expected utility of the future depends on available consumption in
two possible states of the world. If climate change does not occur, out-
put is a function of capital, $K_2 = K_1 + I_1$, and fossil fuel availability,
$D_2 = S - D_1$. Thus, given the same production function defined in (4),
output is

$$F_2 = F(K_1 + I_1, S - D_1) \tag{6}$$

with probability $(1 - P_f)$. If climate change does occur then output is

$$\tilde{F}_2 = F(\left[K_1 + I_1\right] \cdot \left[1 - f(D_1)\right], S - D_1) \tag{7}$$

with probability P_f. Given that we represent the utility of the entire
future as U_2, no investment in any succeeding generation occurs, so con-
sumption is equal to output for "generation two." Thus, expected utility is

$$E(U_2) = (1 - P_f) \cdot U_2(F_2) + P_f \cdot U_2(\tilde{F}_2). \tag{8}$$

or the probability weighted sum of future utility if climate change does
not occur and future utility if climate change does occur.

We assume that no individuals overlap between the present and suc
ceeding generations and view the decisions on I_1, investment in the future
by the first generation, and depletion of fossil fuels by generation 1,
D_1, in a purely ethical context. Thus, using the criteria of the preceed-
ing sections, "ethical" solutions to the decision problem over investment
and fossil fuel depletion are derived from the following optimization
problems :

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Utilitarian (Benthamite)	$\max U_1 + E(U_2)$	(9)
Total Egalitarian (Rawlsian)	$\max \min \{U_1, E(U_2)\}$	(10)
Total Elitist (Nietzschean)	$\max \max \{U_1, E(U_2)\}$	(11)
Libertarian (Paretian)	$\max U_1$ s.t. $E(U_2) \geq U_2^0$	(12)

where U_1 and $E(U_2)$ are defined by (4) - (8) above and U_2^0 in (12) is the initial position (in expected utility) for the future. We analyze outcomes for each of the four criteria below. However, each of the criteria yields as a condition for use of fossil fuels in the present $(D_1 > 0)$ that:

$$F_{D_1} > \left(\frac{1}{1+d}\right)\left(F_{D_2} + P_f \cdot F_{K_2} \cdot f'K_2\right) \qquad (13)$$

when the terms in (13) are evaluated at $D_1 = 0$. Expression (13) simply states that the marginal benefits of fuel use in period one (increase in output or GNP for an increase in D_1, F_{D_1}) must exceed the discounted (d is defined as the discount rate) sum of marginal benefits of future fossil fuel use (F_{D_2}) plus marginal expected damages to the future from combustion in period one $(P_f F_{k_2} f'K_2)$. if the inequality in (10) is reversed, then $D_1 = 0$. The ethical criteria are entirely embodied in the discount rate, d, which weights relative benefits and costs to present versus future generations. Thus, the analysis of our ethical criteria here takes the form of an analysis of the discount rate.

The discount rate in cases where investment in the future by the . present, I_1, <u>is</u> possible and occurs is generally equal to the expected market rate of return of future investment, r, which is defined, in our model as

$$r = (1 - P_f f) \cdot F_{k_2} - 1. \qquad (14)$$

Thus, the marginal productivity of future capital, F_{k_2}, is adjusted for uncertain losses due to climate change $(1 - P_f f)$. The role of investment in future generations in this model is to provide compensation to satisfy the ethical criteria while allowing (14) to hold as a traditional efficiency criterion from economics. if investment as compensation is not possible then we will show that (14) is irrelevant in the analysis.

Table 1 summarizes the results of a detailed analysis of the model. in the Utilitarian Ethic if investment is possible then the appropriate discount rate is the market rate of return. This occurs, because investment allows a net gain in total utility satisfying the Utilitarian criterion of greatest total utility. If, however, investment as compensation is not possible, the discount rate depends on the relative marginal utilities between generations, so

$$d = \frac{U_1'}{U_2'} - 1 \tag{15}$$

giving a range of discount rates from -1 to $+ \infty$.

In the totally Egalitarian or Rawlsian case, the discount rate depends on whether or not an egalitarian solution where $U_1 = E(U_2)$ is achievable. There are three possible cases. In case (a), U_1 cannot be brought "up" to $E(U_2)$ even when $D_1 = S$ and $I_1 = 0$ 0 so the discount rate on the future is always $+ \infty$. In case (b), where an egalitarian solution is achieved, the discount rate exceeds or equals the market rate of return if compensation (investment) is possible but can take on any value, including negative values, if compensation is not possible. In case (c), the first generation is Initially better off than the future. If investment in the future is possible, then U_1 can be brought down and $E(U_2)$ brought up through

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investment until equality is achieved so the appropriate discount rate is the market rate of return. However, if compensation is not possible and $E(U_2)$ remains below U_1 then the discount rate is -1, putting an infinite weight on the future, $\frac{1}{1+d} = \infty$.

The Nietzschean criterion depends on whether the present or future can be best off.   In case (a) the present can be best off. Thus, a discount rate of $+\infty$ is placed on the future in all cases.   "Greatness" is achieved in the present and the future is "written off." In case (b), the future is best off.   If investment by the present is possible, then the market rate of return is the appropriate discount rate for decision-making even though present consumption would be held to subsistance and I would take on the greatest possible value. However, if compensation is not possible, the present is written off and an infinite weight is placed on the future, $d = -1$.

Finally, in the Libertarian Ethic, if investment is possible, then it can be used to keep the future as well off as in their initial state, i.e., as well off as before any decision to invest or deplete fossil fuels. This implies the market rate of return is again appropriate as the discount rate.   However, if investment cannot be used to compensate the future for depletion and climate effects, then these actions are not consistent with the Paretian Ethic and the discount rate adjusts to force $D_1 = 0$.

Given the analysis of discount rates presented above, the implications for present use of fossil fuels can be obtained by examining expression (13). Clearly, if $d = \infty$ then $D_1 > 0$. If $d = -1$ then $D_1 = 0$.   In other words, an Infinite discount rate implies fossil fuels should be used to the maximum desirable level in the present, a discount rate of -1 implies additional fossil fuel use is "unethical."

Ethical System	Discount Rate (d)	
	Compensation to future (Investment) is possible $(1 \geq 0)$	Compensation to future (Investment) is not possible $(1 \equiv 0)$
Utilitarian: $\max U_1 + E(U_2)$	$d = r$	$+\infty > d > -1$
Rawisian: case (a) $\max U_1 < E(U_2)$ case (b) $U_1 = E(U_2)$ case (c) $U_2^0 < U_1^0$ or $E(U_2) < U_1$	$d = +\infty$ $d > r$ $d = r$	$d = +\infty$ $+\infty > d > -1$ $d = -1$
Nietzschean: case (a) $\max U_1 > \max E(U_2)$ case (b) $\max E(U_2) > \max U_1$	$d = +\infty$ $d = r$	$d = +\infty$ $d = -1$
Libertarian: $\max U_1$ s.t. $E(U_2) \geq U_2^0$	$d = r$	$+\infty > d > -1$

Table 1. Discount Rates and Ethical Systems.

Perhaps the most important result of the preceeding analysis is that ethics do matter for economic analysis. The traditional economic criterion of discounting future benefits and costs at the market rate of return only holds in special cases and where actual compensation or investment in the future is possible. Of course, by "possible" we really mean politically feasible. Economists often use the notion of "hypothetical" compensation to justify discounting. In an ethical context such arguments play no role whatsoever. Rather, if no actual compensation occurs, the market rate of return has no relevance for discount rates. Discount rates are then determined solely by the ethical criteria employed in the analysis.

Thus, ethical weighting schemes as shown above can "resolve" the question of appropriate discount rate. However, any benefit-cost analysis then becomes conditional on the ethical system chosen. Obviously, different ethical systems will likely give differing policy answers to the CO_2-climate problem. An alternative interpretation of our results helps explain the diversity of observed opinions on issues similar to the CO_2-climate problem. Individuals with egalitarian (Rawlsian), elitist (Nietzschean) or Libertarian viewpoints all accepting the unlikely nature of real compensation to future generations may in their own "ethical" benefit-cost analysis come to differing conclusions as well. This line of argument suggests that individuals in the present generation may well be able to partially internalize the intergenerational externality of climate change through their own ethical beliefs and consequent actions. An alternative approach to imposing a particular ethic on a benefit-cost analysis is then to attempt to discover directly the willingness to pay of the present generation to prevent particular future climate change assuming that the intergenerational externality is already internalized through individual ethical beliefs. We discuss this approach in the next section.

An Experiment in Determining Intergenerational Willingness to Pay

This section discusses an experiment conducted to discover the willingness to pay of the present generation to prevent changes in conditions for future generations.[27] The perspective adopted here is that in addition to preferences for current commodities registered by the present generation, the present generation also has a set of preferences for goods inclusive of climate to endow to future generations That is, present generations would be willing to give up certain amounts of goods and/or services which would allow endowment of future generations. There is a substantial economic literature examining intergenerational dependence of utility, and also on endowing future generations through preservation of certain unique assets.[28] (See Marglin (1963), Rawls (1971), Arrow (1973), Solow (1974), Sandler and Smith (1976)). What this experiment does is to develop an approach to quantify how individuals can potentially make tradeoffs between present consumption and consumption by some future generation. in most instances there are no organized markets for allowing individuals to make this tradeoff with the exception of a few environmental organizations that receive substantial funding for investments in unique natural assets and preservation oriented activities, e.g., Sierra Club and National Wildlife Federation. We attempt to implement an empirical test to discover on an experimental basis the magnitude of the value current generations place on future generations. That is, we wish to discover how much individuals of the current generation are willing to give up to preserve certain environmental attributes for future generations. The study will focus on potential future

reductions in the ozone profile and the implied effects and costs to future generations. If valuation by present generations towards future generations is high enough in terms of their revealed preferences, then traditional benefit-cost analysis can be restructured to consider present generations losses with the valuation they place on future generations without the need for the introduction of a discount rate or trying to infer what future generations' preferences might[29] Thus, this research effort is an attempt to partially remove the difficulties of traditional benefit-cost analysis in applications to problems where there is a substantial time interval between the incidence of costs and benefits of current environmental regulation.

There appears to be five fundamental ways the present generation can provide future generations with environmental commodities or resources.

1. Reduce or eliminate current consumption which has a deleterious effect on future generations.

2. Preserve part or all of a resource for endowment purposes. That is, reserve it from current use in the economy.

3. Endow future generations with sufficient capital or other resources to compensate them for the negative environmental effect.

4. Utilize resources currently so that the probability of a physical or biological irreversibility approaches zero, i.e., production-consumption emphasizing the use of renewable resources.

5. Endow future generations with sufficient knowledge, through current investments In research, so that they can adequately cope with potential environmental hazards.

All of the above are mechanisms whereby present generations can partially or completely compensate future generations for current economic activities which cause losses to the future. These losses may be formally defined as an inward shift of the production or consumption possibilities set for the future as compared to the present generation.

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In this experiment, we shall concentrate efforts on examining in depth only one of these possible mechanisms of endowing the future, and that is through individual decisions on reducing current consumption of certain commodities, stratospheric flight and reduction in use of fluorocarbons, which may cause inconvenience and higher expenditures. It should be noted, however, that these may be less costly approaches toward endowment of future generations than through coordinated public programs for endowment. The efforts described in this section concentrate on revealing individual preferences as regards to the maximum individuals could give up currently and not be worse off given the knowledge that future generations will not be made worse off. In other words, how many units of foregone current consumption can be substituted for increased units of consumption (or reduction of units of environmental loss) by future generations by individuals currently and leave them as well off as they were prior to the transfer.

Many recent studies by economists and others have examined the problem of intergenerational dependence and how choices should be altered to account for this dependence. It is recognized in these studies that current generations have concern for and thereby are affected by what happens to future generations because of actions of the current generation. The underlying motivation may range from a simple concern for the next generation (one's children) and their concern for the next, to a basic desire to see the human race remain economically and socially viable in perpetuity The assumption is that there is a basic altruism of people taken individually or in collective groups toward the preservation of vital resources needed by future generations. This has been expressed often in various Federal documents and statistics: "....the present generation has moral obligation

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to future mankind to conserve in our uses of natural **resources.**"[30] Whether a representative individual of this generation holds the view that there is a "moral obligation" is unclear.

This study is an attempt to determine the economic magnitude of this obligation for one resource, the ozone layer.

A modification and application of the iterative bidding technique was utilized to estimate directly through sample surveys the willingness to pay not to reduce the future endowment of ozone. This approach has been emphasized in valuing a variety of public goods.[31] The experiment discussed here, however, is, to our knowledge, the first application of the iterative bidding technique for valuing intergenerational goods.

The survey was designed to collect three types of information. First, a basic set of socioeconomic information such as age, marital status, and income which might influence individual values for the future was collected. Second, information on an individual's own private response to the public debate concerning the problem of stratospheric ozone depletion was gathered. In particular, respondents were asked if they had switched to nonaerosol products, if such a switch caused an inconvenience, and if the respondents would fly on the SST if given the chance. The third type of information gathered was the respondent's willingness to pay to prevent a given depletion of stratospheric ozone and the potential increases in skin cancer to future generations.[32]

In collecting the willingness to pay information it was necessary to present a precise set of Information that would convey the nature of the problem and the uncertainty attached to it. The particular set of information was:

Contemporary scientists believe that many of man's activities are causing a significant decline in the earth's protective stratospheric ozone shield. Stratospheric flights by aircraft, agricultural use of nitrogen fertilizers, and use of fluoro-carbons are expected to adversely affect stratospheric ozone. This ozone shield protects all forms of life on the earth's surface from the sun's ultraviolet radiation. The total set of impacts of increased ultraviolet radiation may not be well known at this time. however, it is known that increased ultra-violet radiation will lead to an increased incidence of skin cancer among the general population. If man's ozone altering activities continue at present levels, scientists believe that there is a [25,75] percent chance that stratospheric ozone will be reduced within 20 years to levels which will result in an increased incidence of skin cancer in the United States from 143 cases per 100,000 people to 186 cases per 100,000 people. This increased skin cancer incidence will show up in the general population approximately 50 years after the ozone reduction is started. It is possible, however, for man to avert such a re-duction in stratospheric ozone.

Suppose that you could pay a lump sum each year into a special fund which would be used to prevent an increased incidence of skin cancer as a result of decreasing the stratospheric ozone shield. This fund would be used to prevent alteration of the stratospheric ozone shield either by modifying the pattern of man's activities, or by developing techniques that could mini-mize the effects of potential stratospheric pollutants on the stratosphere.

In answering questions 3-7 which follow, note that the pay-ment which would be made would be payment for the welfare of future generations. It would be a payment to aid your children, grandchildren, and great grandchildren. The future will have to bear the greatest burden of today's ozone depleting activi-ties.

There are several distinct elements in this set of information. First, the potential harm resulting from man's ozone altering activities is described in considerable detail. This provides the sample with a consistent base of information on the problem. Specific magnitudes for harm to individuals are represented by the increased incidence of skin cancer. Second, the uncertainty associated with current knowledge of the potential harm and occurance of stratospheric ozone depletion is presented

by a probability statement. Respondents, randomly, were told either there was a 25 or a 35 percent chance that man's activities would result in significant ozone depletion. Third, a payment mechanism was structured which would collect revenue for the purpose of preventing the potential stratospheric ozone depletion and the resulting increase in skin cancer incidence. Finally, the respondent was directly focused on the fact that their payments to prevent an increased skin cancer incidence would really be a payment to aid future generations.

Each respondent was also asked:

What is the most you would pay each year to prevent this reduction of stratospheric ozone from occuring within the next [20] years?

for time intervals of 20, 50, 100, 200, and 500 years. The 20 year interval) given the sample, provides information on the value which individuals place on themselves (and perhaps their descendants) not suffering an increased chance of skin cancer. Bids over the other time periods then, should reflect individual values for the near future only.

Finally, it is possible that a respondent may answer that he is not willing to pay any amount of money to prevent stratospheric ozone depletion. For such responses it is necessary to determine if the zero bid was legitimate. That is, does the respondent truly not value the contingency he is asked to bid upon? In order to make such a determination the following question was asked:

if you answered $0, please indicate why by choosing from the reasons listed below.

A. The chance that there would be a reduction in stratospheric ozone is not great enough to worry about.

B. I don't believe that payments into a special fund would prevent reduction in stratospheric ozone.

C. The increased skin cancer incidence is nothing to worry about.

D. The future can take care of itself.

E. I, personally, probably would not be affected by the increased number of skin cancer cases.

F. Other.

Response "B" indicates the respondent Is unresponsive to the survey, and that his $0 bid is not a reflection of his value. All the other responses to this quest ion are possible reasons for why the respondent does not value the particular contingency. Data was gathered to test the survey instrument by sampling from two classes at the University of Wyoming and-one class at Colorado State University. All the classes were economics classes. [33] The class at Colorado State University was an intermediate microeconomics course and one of the classes at the University of Wyoming was a principles level microeconomics course. One class at Wyoming is to be considered a control class of sorts. This was an environmental economics class which heard lectures on the stratospheric ozone depletion problem in advance. The hypothesis would be that such additional information would influence the respondent's bid

In the discussion of the data which follows, it must be kept in minds that the sample population is very specialized ie., college classes. The purpose of this analysis is to examine the operation of the survey instrument and not to generate policy relevant value estimates. There is absolutely no justification for generalizing the results which follows to a larger population base.

Table 2 presents summary statistics which describe the characteristics for the sample as a whole and for the control class. The first four variables presented in this table indicate the specialized nature of the population which was sampled. The population were largely childless single males approximately 21 years of age. These statistics highlight our statement above that the data presented here are useful as a type of presurvey whose purpose is to test the usefulness of the survey approach in eliciting the value current generations place on the future.

The income statistics presented at the bottom of Table 2 suggest a justification for distinguishing between bids based on current income and expected future income. It would appear to be the case that the survey respondents sampled generally felt that their current annual incomes were about 2/3 of what they expected their future (or permanent) annual income to be. Perhaps this is another reason for not applying the statistics developed here to the general population. An age distribution which included older respondents would allow respondents to bid based on actual permanent incomes rather than hypothetical (or expected) permanent incomes.

Table 2 also indicates a substantial tendency by the respondents to voluntarily substitute to products believed to be less harmful to the environment. For the total sample, 62.1 percent of the respondents stated they switched to nonaerosol products as a result of public information on expected impacts of such products on the stratospheric ozone shield. In making such switches only 5.0 percent of the total sample indicated that they had felt inconvenienced by switching to other products. Although these responses indicate concern for the environment is of substantial importance to the respondents, for the total sample 59.3 percent of the

respondents stated they would fly on the SST, even though it was potentially damaging to the stratosphere. It might be noted that the questions which were asked did not query the respondent as to whether he would fly on the SST to satisfy a curiosity or on a regular basis. This might offer one explanation for the apparent inconsistency in behavior. Another possible explanation might be that substituting to nonaerosol products might be less costly in terms of time, convenience and money, than would be switching to substitutes for flying the SST.

Tables 3 and 4 present means and standard errors for annual bids based on current incomes and on expected future incomes. These statistics are presented partitioned according to whether the stated probability of occurance of stratospheric ozone depletion was 75 or 25 percent. The general pattern of bids appears to be declining as the length of time to the depletion of stratospheric ozone increases. This pattern may suggest that current generations care relatively less for future generations farther and farther away in time. Such a conclusion is also supported by the information presented in Table 5.

Table 5 summarizes the number of legitimate zero bids. By "legitimate" it is meant that the respondent actually places no value on the contingency for which he is asked to bid. Not all zero bids may be legitimate in this sense, because a zero bid could reflect the fact that the respondent has refused to play the game. Examining Table 5, there are 53.6 percent more legitimate zero bids in the total sample for the 500 year current income based bid than for the 20 year bid, assuming a 25 percent probability of occurance and 42.4 percent more zero bids for the 500 years bid than the 20 year bid for the expected income category.

A simple regression analysis was undertaken to determine independent variables of major importance in "explaining" the bids based on expected future income. Table 6 summarizes this analysis. The major explanatory variables appear to be: (1) time; (2) the class sampled from; (3) the probability of ozone depletion; (4) expected future income; (5) marital status; (6) number of children; (7) whether the respondent has switched to nonaerosol products; (8) whether the switch to nonaerosol products had inconvenienced the respondent; (9) the sex of the respondent, and (10) whether the respondent was planning to have children. Both linear and log-linear specifications were used. The strongest variable, in terms of statistical significance, is the time frame variable. The estimated coefficient on this variable is negative which supports the statement discussed earlier that the current generation cares relatively less about generations farther away in time.

The dummy variable for "class sampled from" has rather odd estimated coefficients. The coefficient in the linear case suggests that the Class I sample, in general, is willing to pay $34 less to prevent stratospheric ozone depletion than the other classes sampled. This is a curious result since Class 1 was the control class which received information about the ozone depletion problem prior to answering the survey. It might be expected that the control class would have been made more aware of the nature of the problem, and therefore willing to pay more to prevent the problem.

It is also interesting to note that this regression analysis suggests that married respondents and respondents with children are willing to pay more to prevent ozone depletion. This is to be expected. This result contradicts, however, the possibility that the current generation

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cares little about future generations. In fact, this analysis suggests that a respondent with a child is willing to pay $59 per year more on the average to prevent ozone depletion.

The estimated coefficients on the probability of occurance of ozone depletion is puzzling. It would be expected that as the probability of ozone depletion in creases that people would be will ing to pay more to prevent the depletion. However, the estimated sign is negative, and in the linear case indicates a $.46 decline in willingness to pay to prevent ozone depletion as probability of depletion increases 1 percent.

The variables related to switching to nonaerosol products suggest that those respondents who have switched were willing to pay $83 more per year in the linear case to prevent ozone depletion than those who had not. On the other hand, individuals who had made the switch and were inconvenienced by the switch were willing to pay $43 less than those not inconvenienced.

Although the explanatory power of these regressions are not high (R^2 = .11, and R^2 = .20), the regression perhaps provides some interesting information about current values for the future. Generally speaking, married respondents and respondents with children are more concerned about ozone depletion than single, childless respondents. However, concern with the future declines as the time frame for occurance of ozone depletion increases in length. Respondents who have already taken voluntary personal measures in the face of possible ozone depletion by switching to nonaerosol products are willing to pay more than those who have not already made such changes.

Table 2.   Basic Statistics Describing the Survey Sample.[a]

Variable	Total Sample	Total Sample 75%[c]	25%[c]	Class I[b] 75%	25%
Male	77.9% N=139	76.1% N=71	80.9% N=68	84.2% N=19	93.3% N=15
Age $\leq$ 21 Years	68.2% N=138	66.7% N=72	69.6% N=66	47.4% N=19	53.4% N=15
Single	85.0% N=139	84.7% N=72	86.6% N=67	84.2% N=19	86.7% N=15
No Children	92.9% N=139	93.1% N=72	92.6% N=68	100.0% N=19	93.3% N=15
Plan Children	80.7% N=134	86 8% N=72	81.8% N=66	73.7% N=19	73.3% N=15
Stopped Using Aerosol Products	62.1% N=139	65.3% N=72	59.7% N=67	68.4% N=19	60.0% N=15
Inconvienenced By Switch To Nonaerosol Products	5.0% N=91	8.3% N=48	7.0% N=43	7.1% N=14	0.0% N=10
Would Fly on SST	59.3% N=139	59.7% N=72	59.7% N=67	52.6% N=19	40.0% N=15
Current Income	x=$18,830 S=2095 N=137	X=$17,132 S=2042 N=72	X=$20,712 S=3800 N=65	X=$26,447 S=4955 N=19	X=$20,286 S=5067 N=14
Expected Future Income	X=$30,764 S=1441 N=140	X=$30,132 S=1970 N=72	X=$31,434 S=2121 N=68	X=$29,842 S=2891 N=19	X=$31,000 S=3809 N=15
Parents Income	X=$35,500 S=1644 N=140	X=$29,688 S=2035 N=71	X=$41,654 S=2409 N=68	X=$29,868 S=4268 N=19	X=$35,000 S=4268 N=15

[a] X = mean; S = standard error of the mean; N=sample size on which the statistic was computed.

[b] Class I represents the control class which received lectures on the stratospheric ozone depletion problem prior to completing the survey.

[c] The 75% and 25% numbers refer to the stated probability of occurance of stratospheric ozone depletion.

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Table 3. Means and Standard Errors for Annual Bids to Prevent Stratospheric Ozone Depletion Based on Current Income and Expected Future income Assuming a 75% Probability Occurance.[a]

Time Period For Occurance of Ozone Decline	Current Income		Expected Future Income	
	Total Sample	Class[b] I	Total Sample	Class[b] I
20 years	97.31 (26.25) N=42	106.46 (63.96) N=11	116.26 (25.92) N=70	122.28 (45.40) N=22
50 years	73.26 (21.59) N=42	93.64 (62.96) N=11	131.92 (20.54) N=70	113.72 (44.13) N=22
100 years	56.50 (21.83) N=42	87.91 (62.89) N=11	96.81 (17.86) N=70	105.22 (44.92) N=22
200 years	36.93 (18.61) N=42	72.55 (63.09) N=11	67.81 (14.88) N=70	88.39 (42.33) N=22
500 years	29.36 (17.17) N=42	65.73 (63.44) N=11	51.23 (13.25) N=70	89.17 (44.67) N=22

[a]Standard errors of the means are presented in parentheses. N denotes the sample size on which the reported statistic was computed.

[b]Class I represents the control class which received lectures on the stratospheric ozone depletion problem prior to completing the survey.

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Table 4. Means and Standard Errors for Annual Bids to Prevent Stratospheric Ozone Depletion Based on Current Income and Expected Future Income Assuming a 25% Probability of Occurance.[a]

Time Period For Occurance of Ozone Decline	Current Income		Expected Future Income	
	Total Sample	Class[b] I	Total Sample	Class[b] I
20 years	101.79 (30.56) N=28	165.80 (87.03) N=5	175.50 (27.47) N=66	237.40 (91.68) N=15
50 years	84.25 (29.49) N=28	42.80 (30.70) N=5	144.74 (23.71) N=66	172.80 (73.55) N=15
100 years	47.11 (20.55) N=28	17.40 (14.42) N=5	109.24 (20.42) N=66	117.27 (50.33) N=15
200 years	32.32 (20.39) N=28	0.0 (0.0) N=5	66.83 (16.62) N=66	81.53 (36.13) N=15
500 years	30.54 (20.40) N=28	0.0 (0.0) N=5	59.52 (20.06) N=66	49.87 (25.87) N=15

[a]Standard errors of the means are presented in parentheses. N denotes the sample size on which the reported statistic was calculated.

[b]Class I represents the control class which received lectures on the stratospheric ozone depletion problem prior to completing the survey.

Table 5.   Legitimate $0 Current Income and Expected Future Income Based Bids.

Time Period For Occurance Of Ozone Depletion	Current income				Expected Future Income			
	Total Sample		Class I[a]		Total Sample		Class I[a]	
	75%[b]	25%[b]	75%	25%	75%	25%	75%	25%
20 years	14.3%	7.1%	9.1%	0%	7.1%	1.5%	0%	0%
50 years	14.3%	10.7%	9.1%	0%	8.6%	3.0%	0%	0%
100 years	21.4%	21.4%	18.2%	20.0%	14.3%	6.1%	5.6%	6.7%
200 years	35.7%	46.4%	45.5%	100.0%	25.7%	27.3%	16.7%	40.0%
500 years	40.5%	60.7%	54.5%	100.0%	34.3%	43.9%	22.2%	53.3%
	N-42	N=28	N=11	N=5	N=70	N=66	N=18	N=15

[a]Class I represents the control class which received lectures on the stratospheric ozone depletion problem prior to completing the survey.

[b]The 75% and 25% numbers refer to the stated probability of occurance of stratospheric ozone depletion.

Table 6. Regression Summary for Expected Future Income Based Bids.

Linear Specification	R^2	SE	F	SS
B= -15.70 - .19 (T) - 34.26 (C) + 14.36 (S) + 3.43 (Y) - .46 (P) + .0012 (I) + 75.15 (H) + 59.15 (N) - 15.69 (K) + 83.34 (A) - 43.74 (X) - 1.79 (SST) 　　　(.05)*　　(21.23)***　(21.18)　　　(4.00)　　　(.33)**　(.0005)**　(37.02)**　(29.47)**　(22.93)　　(41.69)**　(33.29)***　(18.77)	.11	169.48	4.22	430
Log-Linear Specification				
B= 6.99 - .65 (T) -.13 (C) + .099 (S) +.28 (Y) - .10 (P) - .07 (I) - .11 (M) + .37 (N) - .11 (K) + .12 (A) - .07 (X) + .04 (SST) 　　　(.08)*　(.05)*　　(.05)***　(.99)　　(.16)　　(.20)　　(.08)　　(.11)*　(.05)**　(.10)　　(.08)　(.04)	.20	1.83	8.93*	430

Variables definitions are:
  B = bid to prevent stratospheric ozone depletion
  T = time frame for occurance of stratospheric ozone depletion
  C = class sampled from; 1 = class I, 0 otherwise
  S = sex, 1 = female, 0 = male
  Y = age
  P = probability of ozone depletion
  I = expected annual future income
  M = marital status; 1 = married, 0 = single
  N = number of children
  K = 1 denotes planning to have children in the future
  A = 1 denotes switch away from aerosol products
  x = 1 denotes Inconvenienced by switch from aerosol products
 SST = 1 denotes would fly on an SST
 SE = standard error of the regression
  F = F-value for the hypothesis that all estimated coefficients are zero
 SS = sample size

  *Statistically significant at 99% significance level for a two-tailed t-test.
 **Statistically significant at 95% significance level For a two-tailed t-test.
***Statistically significant at 90% significance level for a two tailed t-test.

Conclusions

In this paper, we have attempted to Illustrate that the CO_2 problem is one of intergenerational choice where traditional benefit-cost analysis is inappropriate. It was demonstrated that depending on ethical beliefs, the structure of benefit-cost analysis, particularly with regard to the selection of a discount rate, is altered substantially. The inadequacy of current estimates of economic costs or benefits resulting from 4-6°C increase in global temperature and changes in precipation suggest that the CO_2 problem needs to be analyzed in the context of uncertainty as to impacts on future generations.[34] One method of valuing future effects is to estimate willingness to pay by present individuals to avoid environmental risks to future generations. The estimate of willingness to pay embodies the present generations ethical beliefs and thus avoids (or postpones) a decision on establishing an "optimal" environmental ethic for future generations.

For the CO_2 problem, a number of research recommendations are forthcoming from our analysis. First, studies need to be conducted to refine and estimate the probable economic effects of a gradual but pronounced warming of the terrestial environment. Second, much research is needed into the "optimal" ethic or mix of ethics appropriate to evaluating intergenerational choice problems where the future generations are not necessarily better off. Third, evaluative mechanisms need to be studied on creating "formal" markets for bidding on the environment attributes to be preserved for future generations.

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Endnotes

1. The application of benefit-cost analysis has had a long and tortuous history in federal natural resource agencies. See 0. Eckstein, Water Resource Development : The Economics of Project Evaluation. Cambridge, Mass : Harvard University Press (1958); J.V. Krutilla, "Welfare Aspects of Benefit-Cost Analysis," in S.C. Smith & E.N. Castle, eds., Economics and Public Policy in Water Resource Development, Ames: Iowa (1964).

2. See R. d'Arge, et.al., Economic and Social Measures of Biologic and Climatic Change, U.S. Department of Transportation, (1975); R. d'Arge, et.al., "Benefits and Costs of Regulating Fluorocarbons 11-12," Final Report, University of Wyoming to USEPA, (1976), J.A. Laurman, "Economic impact of CO_2-Induced Climatic Change," Division of Applied Mechanics, Stanford University (July, 1979); M. Bailey, "Uncertainties and Benefit-Cost Analysis of CFC Control," University of Maryland (February 1, 1980).

3. For example, current estimates of the net costs of a gradual warming in the United States depend crucially on whether future increased air conditioning costs will be greater than benefits from reduced heating costs which are both sensitive to assumptions on future energy prices and location of populations in the continental U.S. See R. d'Arge, "Climate and Economic Activity," paper presented to the World Climate Conference, WMO, Geneva, Switzerland (February, 1979).

4. There is substantial indirect evidence that individuals are willing to pay some proportion of their current income to endow future generations with certain types of assets, e.g., National Parks, historical monuments, lack of nuclear waste materials, species preservation. The classic paper on this idea is J.V. Krutilla, "Conservation Reconsidered," American Economic Review, (August, 1967).

5. Report of the Panel on Energy and Climate, Energy and Climate, National Academy of Sciences, Washington D.C. (1977). See also, G. Woodwell, et. al., "The Carbon Dioxide Problem: Implications for Policy in the Management of Energy and other Resources," A Report to the Council on Environmental Dual Quality, Washington, D. C. (July, 1979).

6. W.W. Kellogg, "Influences of Mankind on Climate," Annual Review Of Earth and Planetary Sciences, (1979).

7. S. Wittwer, Remarks to the National Academy of Sciences Workshop on Critical Future Environmental Issues, Washington, D.C. (November, 1979).

8. See I. Heah, "Climate, Energy Use, and Wages," in J.H. Cumberland, ed. Economic Aspects of Effects upon Health and Climate from the Management and Control of Ozone Depletion, Washington, D.C.: U.S. Environmental Protect ion Agency, (1979).

9. I. Heah, op. cit.

10. See M. Bailey (February, 1980) op. cit.; K. Attaran, Inter-Metropolitan Budget Cost Determinants: An Econometric Analysis, unpublished Ph.D. dis- sertation, University of Southern California, (1973), and R. d'Arge (1975) op. cit.

11. Neidercorn examined the capital costs involved in a shift in the U.S. cornbelt "potentially" induced by stratospheric effects of SST's. See J. Neidercorn, "The Capital Costs of Climatically induced Shifts: The Example of the American Corn Belt," in T. Ferrar, ed., The Value Costs of Climate Modification, New York: John Wiley (1976).

12. Laurman suggests the lead time necessary to convert to nonfossil fuel s may be the important considerations for CO_2 induced climate change. See J. Laurman, (July, 1978) op. cit.

13. From R. d'Arge, et. al., (1976) op. cit., R. d'Arge (1970), op. cit. and J. Laurman, (1979) op. cit.

14. This question has been raised by several authors including Mishan and Page. See E. Mishan & T. Page, "The Methodology of Cost-Benefit Analysis--with Particular Reference to the Ozone Problem," presented at the EPA-University of Maryland Conference on Ozone Management, Port Depnit, Maryland (1979).

15. A story defense of this approach for the ozone problem is given by Bailey who suggests "allowing ethical considerations to influence the choice of a discount rate directly forces mismeasurement of real costs..." See Bailey (February 1, 1930) op. cit.

16. T. Page, Conservation and Economic Efficiency, Baltimore, Johns Hopkins, 1977.

17. J. Laurman, (1979) op. cit.

18. This discussion draws heavily upon, A Study of the Ethical Foundations of Benefit-Cost Analysis Techniques, by Ben-David, Kneese and Schulze (Final Report to the National-Science Foundation, August, 1979).

19. Alexander, Sidney S.: "Social Evaluation Through National Choice," Quarterly Journal of Economics, LXXX VIII, No. 4, November, 1974.

20. For a fascinating discussion of the ethics of lying, see Sissela Bok, Lying, New York, Vintage Books, 1978.

21. J. Rawls, A Theory of Justice, Cambridge, Belknap Press, 1971.

22. An underlying theme of argument proposed by some economists for a "higher" discount rate is that future generations will always be better off because of the saving, technological change, and higher productivity. From an "elitist" view, then the future generations should be protected from CO_2 and from a Rawlsian view they should be ignored.

23. Nozick, R. Anarchy, State, and Eutopia, Basic Books, New York, 1974.

24. A. Rand, The Virtue of Selfishness, American Library, New York, 1964.

25. W. Gass, "The Case of the Obliging Stranger," in R. Wolff, ed. Philosophy : A Modern Encounter, Englewood Clifs, New Jersey: Prentice-Hall, (1976).

26. This analysis is drawn from Schulze and Brookshire, "Economics and Intergenerational Ethics: An Example Application to the CO_2-Climate Change Problem," working paper, University of Wyoming, September, 1979.

27. This section presents results from R. d'Arge, D. Brookshire, and L. Eubanks, "Environmental Values for the Future: A Methodological Experiment on Ozone Depletion," University of Maryland subcontract, USEPA, (September, 1979).

28. Marglin, S.A., "The Social Rate of Discount and the Optimal Rate of Investment," Quarterly Journal of Economics 77, 95-112 (1963); Rawls J., A Theory of Justice, Cambridge, Mass., Harvard University Press (1971); Arrow, K.J., "Rawl's Principle of Just Saving," Swedish Journal of Economic 323-335 (1973); Solow, R.M., "Intergeneration Equity and Exhaustible Resources," Review of Economic Studies, symposium (1974); and Sandler, T. and Smith, V.K., "Intertemporal and Intergenerational Pareto Efficiency," Journal of Environmental Economics and Management, Volume II 151-159 (1976)

29. However, this does not preclude the need to establish the correct combination of ethical beliefs of the existing or future generations. These must be known to implement the "correct" form of benefit-cost analysis.

30. U. S. Long-Term Economic Growth Prospects: Entering a New Era, Staff Study, Joint Economic Committee, U.S. Congress, January 25, 1978.

31. Randall, et.al., "Bidding Games for Valuation of Aesthetic Environmental Improvements,"' <u>Journal of Environmental Economics and Management</u>, Volume I (1974); Hammack, J. and Brown, G.M., <u>Waterfowl and Wetlands: Towards Bioeconomic Analysis</u>, Baltimore: Johns Hopkins University Press (1974); Brookshire, D., Ives, B., and Schulze, W., "The Valuation of Aesthetic Preferences," <u>Journal of Environmental Economics and Management</u>, Volume 3 (1976); Rowe, R., d'Arge, R., Brookshire, D., (forthcoming), "An Experiment on the Economic Value of Visibility." <u>Journal of Environmental Economics and Management</u>; Brookshire, D., Randall, A., and Stoll, J., "Valuing Increments and Decrements in Natural Resource Service Flows." <u>American Journal of Agricultural Economics</u>, (forthcoming (b)); Brookshire, D., d'Arge, R., Schulze, W., and Thayer, M., (forthcoming (a)), "Experiments in Valuing Public Goods," ed. by V.K. Smith in <u>Advances in Applied Micro-Economics</u>, JAI Press, Inc.

32. While the CO_2 problem is generically different In that the effects are now not inclusive of "cancer," the approach taken here could be readily adopted if there were sufficient information on the physical and biological effects. In our opinion, the words "disaster" or "catastrophe," while being used extensively in the CO_2 debate, are meaningless.

33. University students may not be self-sufficient, nor is it likely that if self-sufficient they have achieved their permanent income level. For these reasons, respondents were asked to state their willingness to pay to prevent ozone depletion and increased skin cancer first based on current income and then on their expected future annual income.

34. In a recent issue of <u>Science,</u> the actual temperature changes from a CO_2 buildup have been estimated to be only 1/10 of previous estimates. See "The Climatological Significance of a Doubling of Earth's Atmospheric Carbon Dioxide Concentration," by S.B. Idso, <u>Science,</u> Volume 207, (March 28, 1980).

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